

Feeding in Syntopy: Diet of *Hydromedusa tectifera* and *Phrynops hilarii* (Chelidae)

LEANDRO ALCALDE^{1,2,3}, NATACHA NARA DEROCOCCO¹, AND SERGIO DANIEL ROSSET^{1,2}

¹Sección Herpetología, Instituto de Limnología Dr R.A. Ringuelet, CC 712, CP 1900, La Plata, Buenos Aires, Argentina
[alcalde@ilpla.edu.ar; puconpay@yahoo.com.ar; rosset@ilpla.edu.ar];

²Sección Herpetología, Museo de La Plata, Paseo del Bosque s/n, CP 1900, La Plata, Buenos Aires, Argentina;

³Investigador Asistente, Conicet

ABSTRACT. – Stomach contents were obtained from 25 *Hydromedusa tectifera* and 47 *Phrynops hilarii* that live in syntopy in a pampasic stream in Buenos Aires province, Argentina. Both species are arthropod consumers. Copepods, ostracods, and hemipterans are the preferred items for *P. hilarii*, and *H. tectifera* prefers copepods, ostracods, immature dipterans (mainly chironomids), and ephemeropteran larvae. Items that most contribute to the diet of both species are immature chironomids, corixids, and belostomatids. Available food varies little among seasons, being slightly lower in winter months and part of the summer. Diet diversity changes by seasonal variation of prey item abundance in the diet of both species. Diet diversity is higher for *P. hilarii* (more generalist and broader trophic niche) than in *H. tectifera*, but there is no niche overlap between them. No significant correlation between the size of turtles and length of prey items was found. There is no evidence that the long neck of *H. tectifera* relates to piscivorous habits, because fish are a small fraction of its diet and arthropods constitute the bulk of the ingested items.

KEY WORDS. – Reptilia; Testudines; Pleurodira; Chelidae; *Hydromedusa tectifera*; *Phrynops hilarii*; diet; feeding; piscivory; Argentina

Most of the present knowledge about diet of freshwater turtles is somewhat unbalanced toward cryptodirans, with emydids and kinosternids the most studied (Raney and Lachner 1942; Lagler 1943, 1966; Knight and Gibbons 1968; Mahmoud 1968; Moll and Legler 1971; Dodd et al. 1988; Chen and Lue 1998; Stuart and Painter 2002; Ottonello et al. 2005; Collins and Lindeman 2006; Lindeman 2006a, b). Dietary aspects of pleurodirans based on large field-collected data sets are known for about the 20% of the species described for the group (Chessman 1986; Lima et al. 1997; Allanson and Georges 1999; Souza 2004; Armstrong and Booth 2005; Caputo and Vogt 2008; Wilson and Lawler 2008, among others). Other works about diet of pleurodirans are documented in captive specimens and miscellaneous field observations (e.g., Luederwaldt 1926; Gallardo 1987; Malvasio et al. 2003).

There are no detailed long-term studies describing the diet of the most austral species of South American pleurodirans, *Hydromedusa tectifera* and *Phrynops hilarii*. The only published data for the diet of *P. hilarii* are those of Richard (1999) and Gallardo (1982). The first author considered *P. hilarii* an unspecific hunter of prey smaller than the turtle head, whereas Gallardo (1982) characterized the species as predominantly a herbivore. Luederwaldt (1926), Gallardo (1956, 1987), and Freiberg (1977) supplied some comments on the diet of *H. tectifera* and noted that the species consumes arthropods, fish, anurans, and gastropods (*Pomacea*).

This study characterizes the trophic niches of the long-necked *H. tectifera* and the short-necked *P. hilarii* living in syntopy in a polluted stream in Argentina at their austral limits of distribution (Derocco et al. 2005) and

seeks to 1) describe the trophic spectrum of both species and characterize each one as a specialist or generalist, 2) analyze the trophic niche overlap between the species, 3) evaluate the variation of the frequency of each prey item among seasons, and 4) describe the relationship between turtle size and prey item size. Additionally, we discuss the hypothesis of piscivory, as introduced by Pritchard (1984), by comparing the diet of *P. hilarii* and *H. tectifera* in the context of data for other freshwater turtles.

MATERIALS AND METHODS

The study was conducted at Arroyo Buñirigo (35°01'S; 57°29'W, Buenos Aires Province, Argentina), a stream in the Río de La Plata drainage. Turtles were trapped in 2 sample stations. Sample station 1 was under the influence of the Río de La Plata with daily changes of water depth (0.2–2.5 m) and mostly native vegetation on its margins (e.g., *Celtis tala*, *Erythrina crista-galli*, *Passiflora caerulea*, *Salix humboldtiana*, *Schinus longifolius*, *Senna corymbosa*, *Vigna luteola*) with presence of some introduced shrubs (*Lonicera japonica*) and trees (*Morus* sp., *Ligustrum* sp., *Phoenix* sp.). Sample station 2 was more homogeneous in depth (usually 1 m) except during the rainy season. This area had elevational changes at some points, creating small waterfalls (0.5 m height). Cattle ranching in the area impacts the vegetation of the stream banks, leaving some native trees (*C. tala*, *S. longifolius*, *S. corymbosa*) and a few exotic trees (*Morus* sp., *Phoenix* sp.). Submersed and floating vegetation is scarce (lower than 25%), and the bottom is hard in both areas.

Samples were taken once each month (or bimonthly) from December 2006 to November 2008, a total of 18 sample days. Turtles were trapped using 3 different methods: single-funnel traps, double-funnel traps, and fishing lines without hooks. Characteristics of structure and functioning of the single-funnel traps are specified in Colautti (1998). Double-funnel traps are rectangles that were constructed using a 5-mm net. They are opened at both ends and with ample distance between the external (40 × 40 cm) and internal (15 × 15 cm) openings of each funnel. In all cases, we used cow-heart as bait. We put 1 double-funnel trap, 1 single-funnel trap, and 2 fishing lines (20 baits) at each sample station for a period of 24 h and checked the traps and replaced the bait balls at 12-h intervals.

Each turtle was taxonomically identified, sexed, weighed, and measured (straight-line carapace length, maximum carapace width, and maximum head width). Length measurements were obtained using calipers (± 0.1 mm) and weights by a digital balance (± 1 g). Males of both species were recognized by the presence of a plastral concavity (see Cabrera 1998). Females of both species lack a plastral concavity. *Hydromedusa tectifera* males have a plastral concavity from hatching, and both sexes are identifiable at all sizes. *Phrynops hilarii* males begin to have a plastral concavity at 180-mm carapace length (L. Alcalde, *pers. obs.*); specimens were considered males (concavity present) or females (concavity absent) when they were longer than 180 mm, whereas smaller individuals were considered juveniles.

Stomach contents were obtained by flushing, following the principles described by Legler (1977) with modifications, and preserved in 70% ethanol. The offer (environmental abundance of aquatic prey items) was estimated passing a hand-net (50-cm diameter, mesh 0.1 mm) 30 times along the vegetated margins and bottoms of each sample station. Fish trapped with the funnel traps were also recorded for prey estimations. Prey items were preserved in 70% ethanol. Water and air temperature ($\pm 1^\circ\text{C}$) were registered.

Stomach contents and prey items were taxonomically classified to order or family level and counted. We measured the maximum length and maximum width of each flushed item using a stereoscopic microscope with measurement accessories (± 0.1 mm) to estimate the volume of each item, employing the ellipsoid method (Dunham 1983).

The contribution of each item to the diet was evaluated using the Relative Importance Index (Pinkas et al. 1971) as follows: $\text{RII} = \%OF [\%V + \%N]$, where $\%OF$ indicates the percent of the stomachs containing a particular prey item, $\%V$ is the proportion of the volume of each item in relation to the total volume of all prey items, and $\%N$ represents the proportion between the number of individuals of each item and the total of individuals of all prey items. The prey item with the highest value of RII was used to make the percent category of RII values of the remaining ones. The following categories were considered: fundamental (RII

values between 50.1 and 75%), secondary (between 75.1 and 100%), accessory (25–50%), and accidental (lower than 25%). The RII was calculated for items grouped at Family level (e.g., Pimelodidae and Loricariidae for siluriform fish or Corixidae, Notonectidae, Ranatridae, and Belostomatidae for hemipteran arthropods) or at high taxonomic levels (e.g., Hydrudinea and other categories that could not be identified with better accuracy). In addition, we calculated this index discriminating prey items as larvae or adults in the case of particular groups (e.g., Coleoptera, Anura, and Diptera).

To evaluate diet preference, we calculated the Ivlev index (IvI) (Ivlev 1961) as follows: $\text{IvI} = \%n_d - \%n_o / \%n_d + \%n_o$, where $\%n_d$ indicates the numerical proportion of each prey item in relation to total items in the diet, and $\%n_o$ is the same but for offer items. The IvI index was calculated for aquatic items grouped at Order level (e.g., Siluriform for some fish or Hemiptera for some arthropods). Values of IvI tending to -1 indicate avoidance of the prey, whereas values tending to 1 denote a major prey preference.

Diet diversity of both species and diversity of the prey were calculated using the Shannon diversity index (H') applying natural logarithms (Shannon and Weaver 1949). Comparisons among the 3 H' indices (H' prey, H' *Phrynops* diet, H' *Hydromedusa* diet) were made using t -tests.

The breadth of the trophic niche was calculated employing the index proposed by Levins (1968) based on Shannon diversity index: $H = -\sum p_i \times \log_2 p_i$, where p_i is the number of each item considering the total of stomachs. Higher values of the index indicate lower diet specialization.

To calculate niche overlap, we used the symmetric index proposed by Pianka (1973, 1974): $O_{jk} = \frac{\sum p_{ij} \times p_{ik}}{\sum p_{ij}^2 + \sum p_{ik}^2}$, where $p_{ij} \times p_{ik}$ represents the proportion of each item employed for species j and k . This index generates values between 0 (with no overlap of the diet) and 1 (complete overlap).

To test whether prey composition varies between juveniles and adult males and between seasons (autumn–winter vs. spring–summer), we employed Chi-square tests (χ^2) using Yates correction factor. Our null hypothesis (H_0) for these comparisons was that the number of prey items of each category does not vary between pairs of comparisons (autumn–winter vs. spring–summer, males vs. juveniles). Prey items were grouped into inclusive categories to make Chi-square comparisons (e.g., belostomatids, corixids, notonectids, and ranatrids were considered as Hemiptera). In all cases, categories with total values lower than 2 were not compared.

Seasons were grouped by comparing the mean water temperature of the whole year with the mean of each season, yielding 2 groups: autumn–winter ($T < 19.8^\circ\text{C}$) and spring–summer ($T > 19.8^\circ\text{C}$). This pair of seasons was used to evaluate seasonal variation of the diet.

To test whether prey size varies in relation to the size of the turtles, we used Pearson's correlations between carapace length and mean length of the prey ingested by each turtle.

All analyses were made using the software STATISTICA 6.0 (StatSoft 2001) considering only the animal fraction of the diet, excluding plant matter, stones, bait rests, and parasitic nematodes.

RESULTS

Twenty-five *H. tectifera* (4 females, 21 males) and 64 *P. hilarii* (16 females, 33 males, 15 juveniles) were caught at Arroyo Buñirigo during this study. Stomach contents were obtained for all *H. tectifera* and for 47 specimens of *P. hilarii* (9 females, 27 males, 11 juveniles). Small stones were present in stomachs of 4 *H. tectifera* (16%; 3 males, 1 female) and 4 *P. hilarii* (8.5%; 1 male, 1 juvenile, 2 females). Plant material was present in stomachs of 9 males of *H. tectifera* (36%) and 15 *P. hilarii* (31.9%; 8 males, 4 juveniles, 3 females). Although plant material had a high frequency of occurrence in both species, the highest volume was verified for *P. hilarii* (61 fragments, 10.74 ml, 8.2% of the volume of all food items). Plant fragment composition in *P. hilarii* was 28 flowers, 10 leaves, 6 grasses, 4 fruits (*Morus* spp.), 4 stems, 4 small floating plants, 3 seeds, and 1 root. In *H. tectifera*, plant fragment composition was 14 grasses, 11 leaves, 1 root, and 2 entire small floating plants that totalled 1.66 ml (3.2% of the volume of all food items). The frequency of plant material in the stomach contents of both species was moderately high. Considering the composition of plant material (generally incomplete fragments), we discard the hypothesis of herbivory for both species. We believe that vegetal ingestion occurs accidentally when turtles prey upon other items or by confusing plant parts with terrestrial insects that float on the surface of the water.

Twenty nematodes were obtained from the stomachs of 8 individuals of both sexes of *H. tectifera*. Similarly, we found 24 nematodes in 8 specimens of both sexes of *P. hilarii*. Nematode sizes ranged 4–35 mm in *H. tectifera* and 18–35 mm in *P. hilarii*, and in some cases, they were flushed alive.

The animal items recorded in the diet of both species are in Table 1. This shows the percentage of numeric frequency (%NF), percentage of observed frequency (%OF, percentage of turtles with the food item), and percentage of the total volume of all food items (%TV) for each species. Of the animal items preyed upon by *P. hilarii*, 99.3% were arthropods, with clear prevalence of microcrustaceans (50.3%) and immature chironomids (30.2%) (Fig. 1A). Similarly, 99.5% of the items ingested by *H. tectifera* were arthropods, especially immature chironomids (82%), crustaceans (8.8%, mostly microcrustaceans), and adult insects (7.2%) (Fig. 1D). Within the "other items" category described in Figure 1A and D, fish were the most common in *H. tectifera* (Fig. 1E), with

gastropods the predominant one in *P. hilarii* (Fig. 1B). In both species, the fraction of terrestrial items was lower than 1%, being slightly higher in *P. hilarii* than in *H. tectifera* (Fig. 1C, F).

Ivlev's Index indicates that copepods (IvI: 0.99), ostracods (IvI: 0.93), and hemipterans (IvI: 0.32) are the most preferred aquatic food items in *P. hilarii*. In *H. tectifera*, the most preferred aquatic food items are copepods (IvI: 0.99), ostracods (IvI: 0.85), immature chironomids (IvI: 0.8), and ephemeropteran larvae (IvI: 0.51).

The Relative Importance Index indicates that immature chironomids (RII: 100) and hemipterans of the families Corixidae (RII: 50.9) and Belostomatidae (RII: 9.18) are the items that most contribute to *H. tectifera* diet. Identical results, but with more equal contribution of corixids and belostomatids, was found for *P. hilarii*: immature chironomids (RII: 100), Corixidae (RII: 26.17), and Belostomatidae (RII: 20.03). Values of RII showing the dietary contribution of all food item categories in both species are in Table 2.

The temporal evolution of the H' indices for the offer and the stomach contents of both species are in Figure 2. This graph shows 2 results: 1) available prey diversity did not vary much during the present study, being lower during winter months and in parts of the summer; and 2) diet diversity of both species varied, resulting in temporal differences of prey being consumed.

The H' index of the prey abundance was higher than the H' values obtained for the diet of both species, with the diet of *P. hilarii* being more diverse than that of *H. tectifera* ($H_{prey} = 0.99$; $H_{Phrynops} = 0.68$; $H_{Hydromedusa} = 0.33$). The H values of both species differed ($t = 56.45$, $v = 15,210$, $\alpha = 0.05$) and when each them was compared with prey abundance ($H_{Phrynops}$ vs. H_{prey} : $t = 51.61$, $v = 15,210$, $\alpha = 0.05$; $H_{Hydromedusa}$ vs. H_{prey} : $t = -107.9$, $v = 189,473.6$, $\alpha = 0.05$). In addition, values calculated for the breadth of the trophic niche of *P. hilarii* ($H = 2.248$) and *H. tectifera* ($H = 1.06$) indicate that *P. hilarii* is more generalist than *H. tectifera* because of the lower value obtained for the latter species. The value of the symmetric index used to calculate trophic niche overlapping was near zero ($O_{jk} = 0.000035$), indicating the almost total absence of niche overlapping between both species.

When the prey item category abundance was compared between both groups of seasons (autumn–winter vs. spring–summer), we observed that particular items showed significant differences in both species (Table 3). In *H. tectifera*, 6 of 11 categories showed significant variation on prey item abundance between seasons. The species consumes more naiads, larval ephemeropterans, and immature dipterans in the coldest months than in spring–summer. Conversely, higher consumption of hemipterans, crustaceans, and fish characterizes the warmest months.

Table 1. Percentages of numeric frequency (%NF), occurrence frequency (%OF), and total volume (%TV) of each prey item category for both studied species. Spaces without data indicate absence of the item in the diet of the species.

| Food item | <i>H. tectifera</i> | | | <i>P. hylarii</i> | | |
|--|---------------------|-----|--------|-------------------|-------|--------|
| | %NF | %OF | %TV | %NF | %OF | %TV |
| Siluriform fish | | | | | | |
| Loricaridae | | | | 0.02 | 2.22 | 0.14 |
| Pimelodidae | 0.086 | 12 | 10.5 | | | |
| Characiform fish | | | | | | |
| Characidae | 0.065 | 16 | 3.41 | 0.07 | 20 | 2.98 |
| Cyprinodontiform fish | | | | | | |
| Poeciliidae | 0.108 | 8 | 0.34 | 0.006 | 4.44 | 0.01 |
| Anura | | | | | | |
| Hylidae (larvae) | | | | 0.06 | 2.22 | 0.2 |
| Birds | | | | | | |
| Feathers, unidentified family | | | | 0.01 | 4.44 | 3.51 |
| Mammalia | | | | | | |
| Hair and skin rests, unidentified family | | | | 0.01 | 6.66 | 17.1 |
| Testudines | | | | | | |
| Mental barbels, Chelidae (<i>P. hylarii</i>) | 0.01 | 4 | 0.01 | | | |
| Cnidaria | | | | | | |
| Hydrozoa, <i>Hydra</i> spp. | | | | 0.06 | 2.22 | 0.007 |
| Platyhelminthes | | | | | | |
| Turbellaria, unidentified family | | | | 0.006 | 2.22 | 0.003 |
| Mollusca, Gastropoda | | | | | | |
| Ampullaridae | | | | 0.006 | 2.22 | 0.002 |
| Hydrobiidae | 0.054 | 8 | 0.21 | 0.52 | 8.88 | 0.62 |
| Planorbidae | 0.021 | 8 | 0.03 | | | |
| Annulata | | | | | | |
| Hirudinea, unidentified family | | | | 0.06 | 4.44 | 2.19 |
| Oligochaeta, unidentified family (aquatic) | | | | 0.006 | 2.22 | 0.0001 |
| Arthropoda, Chelicerata | | | | | | |
| Araneidae, Lycosidae | | | | 0.012 | 4.44 | 0.008 |
| Acari, Arrenuridae | 0.032 | 8 | 0.0006 | 0.006 | 2.2 | 0.0002 |
| Arthropoda, Crustacea | | | | | | |
| Cladocera, unidentified family | | | | 25.47 | 2.22 | 0.27 |
| Ostracoda, unidentified family | 0.173 | 20 | 0.001 | 0.42 | 15.55 | 0.008 |
| Copepoda, unidentified family | 5.227 | 24 | 0.13 | 25.47 | 2.22 | 0.21 |
| Amphipoda, Hyalellidae | 1.76 | 40 | 1.58 | 1.77 | 11.11 | 0.83 |
| Decapoda, Brachyura, Trychodactylidae | | | | 0.006 | 2.22 | 0.002 |
| Decapoda, Sergestidae | 0.01 | 4 | 0.99 | | | |
| Isopoda, unidentified family (terrestrial) | | | | 0.012 | 2.22 | 0.22 |
| Arthropoda, Insecta, Hemiptera | | | | | | |
| Heteroptera, Belostomatidae | 0.097 | 24 | 10.64 | 0.16 | 33.33 | 12.29 |
| Heteroptera, Notonectidae | 0.076 | 16 | 0.34 | 0.006 | 2.2 | 0.02 |
| Heteroptera, Corixidae | 8.47 | 36 | 30.49 | 12.67 | 20 | 14.45 |
| Heteroptera, Ranatridae | 0.01 | 4 | 0.12 | | | |
| Heteroptera, unidentified family (terrestrial) | | | | 0.01 | 4.44 | 0.0008 |
| Auchenorrhyncha, Cercopidea | | | | 0.03 | 6.66 | 0.01 |
| Arthropoda, Insecta, Lepidoptera | | | | | | |
| Larvae, unidentified family | | | | 0.01 | 4.44 | 0.66 |
| Arthropoda, Insecta, Coleoptera | | | | | | |
| Larvae (Dysticidae, Hydrophilidae) | 0.021 | 8 | 0.02 | 0.05 | 6.66 | 0.03 |
| Adult (Dysticidae, Hydrophilidae) | 0.054 | 16 | 1.38 | 0.35 | 26.66 | 0.8 |
| Adult (Curculionidae and others) (terrestrial) | 0.021 | 8 | 0.08 | 0.15 | 15.55 | 2.21 |
| Arthropoda, Insecta, Orthoptera | | | | | | |
| Acrididae | 0.021 | 4 | 0.04 | 0.01 | 4.44 | 0.0008 |
| Arthropoda, Insecta, Hymenoptera | | | | | | |
| Formicidae | 0.010 | 4 | 0.002 | 0.01 | 4.44 | 0.001 |
| Hymenoptera, unidentified family | | | | 0.01 | 4.44 | 0.001 |

Table 1. Continued.

| Food item | <i>H. tectifera</i> | | | <i>P. hilarii</i> | | |
|--|---------------------|-----|------|-------------------|-------|--------|
| | %NF | %OF | %TV | %NF | %OF | %TV |
| Arthropoda, Insecta, Diptera | | | | | | |
| Chironomidae (larvae) | 81.52 | 24 | 34.8 | 31.96 | 28.88 | 39.77 |
| Culicidae (larvae) | | | | 0.08 | 8.88 | 0.009 |
| Culicidae (adult) | | | | 0.01 | 4.44 | 0.006 |
| Muscidae (larvae) | | | | 0.01 | 2.22 | 0.15 |
| Muscidae (adult) | | | | 0.01 | 4.44 | 0.01 |
| Sirphidae (larvae) | | | | 0.01 | 4.44 | 0.08 |
| Ceratopogonidae (adult) | 0.01 | 4 | 0.05 | | | |
| Simulidae (adult) | | | | 0.006 | 2.22 | 0.0001 |
| Arthropoda, Insecta, Odonata | | | | | | |
| Anisoptera larvae, unidentified family | | | | 0.006 | 2.22 | 0.27 |
| Zigoptera larvae, unidentified family | 0.53 | 24 | 2.41 | 0.04 | 11.11 | 0.12 |
| Arthropoda, Insecta, Ephemeroptera | | | | | | |
| Larvae, unidentified family | 0.9 | 12 | 2.31 | 0.36 | 2.22 | 0.87 |
| Arthropoda, Insecta, Trichoptera | | | | | | |
| Larvae, unidentified family | 0.032 | 4 | 0.03 | 0.006 | 2.2 | 0.002 |

Eight of the 11 item categories preyed upon by *P. hilarii* varied among seasons, with crustaceans, hemipterans, aquatic coleopterans, gastropods, and terrestrial items more abundant in the warmest months. Conversely, the diet of this species shows a higher frequency of ephemeropteran larvae, immature dipterans, and hydrudineans in the coldest months. Immature dipterans, ephemeropteran larvae, and crustaceans correlate with offer variation in the diet of both species. However, both species coincide in a higher consumption of hemipterans in spring–summer than in autumn–winter contrary to the lack of seasonal variation of these insects in the offer.

Seasonal variation of other prey item categories preyed upon by *P. hilarii* also differed from the seasonal variation of these items in the offer. Aquatic coleopterans, naiads, hydrudineans, gastropods, and fish in the diet did not correlate with seasonal variation of these items. Except for gastropods and hemipterans, the diet of *H. tectifera* was more correlated to seasonal variations than was the diet of *P. hilarii*.

Sex variation of the diet could not be made for 2 reasons: 1) the number of females with contents in their stomachs was too small in both species; and 2) the number of items contained in female stomachs was insufficient to perform any statistical analysis. Comparisons between males and juveniles of *H. tectifera* were not made because this species has secondary sexual dimorphism from hatching. For these reasons, comparisons were made only between adult males and juveniles of *P. hilarii* (Table 4). This demonstrates that abundance of hemipterans, naiads, crustaceans, hydrudineans, ephemeropterans, immature dipterans, and gastropods was lower in juveniles than in adult males of the species.

Turtles of both species showed no correlation between the mean size of ingested prey and carapace length of the turtles (Fig. 3A, B). Although there was no significant correlation in either species (Pearson's r

$= 0.0294$, $P > 0.5$; Pearson's $r_{Hydromedusa} = 0.002$, $P > 0.5$), graphs show that larger individuals of *H. tectifera* tend to eat larger preys. The largest prey fed upon by *P. hilarii* was the characiform fish, *Pseudocorynopoma doriai* (total length: 46 mm), whereas the smallest prey was a cladoceran (0.7 mm). The smallest prey ingested by *H. tectifera* was a small copepod (0.5 mm) and the largest was the siluriform fish, *Pimelodella laticeps* (total length: 40 mm).

DISCUSSION

Hydromedusa tectifera and *P. hilarii* are generalist carnivorous species. Both prey upon aquatic and terrestrial arthropods, and their diets have a low contribution of items such as fish, tetrapods (as carrion), larval anurans, and other invertebrates. Plant matter occurs by involuntary ingestion in both species.

Diet Preferences. — Item preference indices have been studied for few species of freshwater turtles because such indices require knowledge of both the diet of the species and the environmental abundance (offer) of prey items. Only Parmenter (1980) for *Trachemys scripta* and Spencer et al. (1998) for *Emydura macquarii* have used these indices. Spencer et al. found that only 1 of the 4 most preferred items of *E. macquarii* also had a high diet contribution. Similarly, Parmenter did not find more than one coincidence between the most preferred and the most important dietary items in the 3 populations of *T. scripta* he studied.

Individuals of *P. hilarii* studied herein preferred copepods, ostracods, and aquatic hemipterans, whereas *H. tectifera* preferred copepods, ostracods, immature chironomids, and ephemeropteran larvae. Among these last items, only immature chironomids coincided in having a high IRI and Ivlev values in *H. tectifera*, with the same

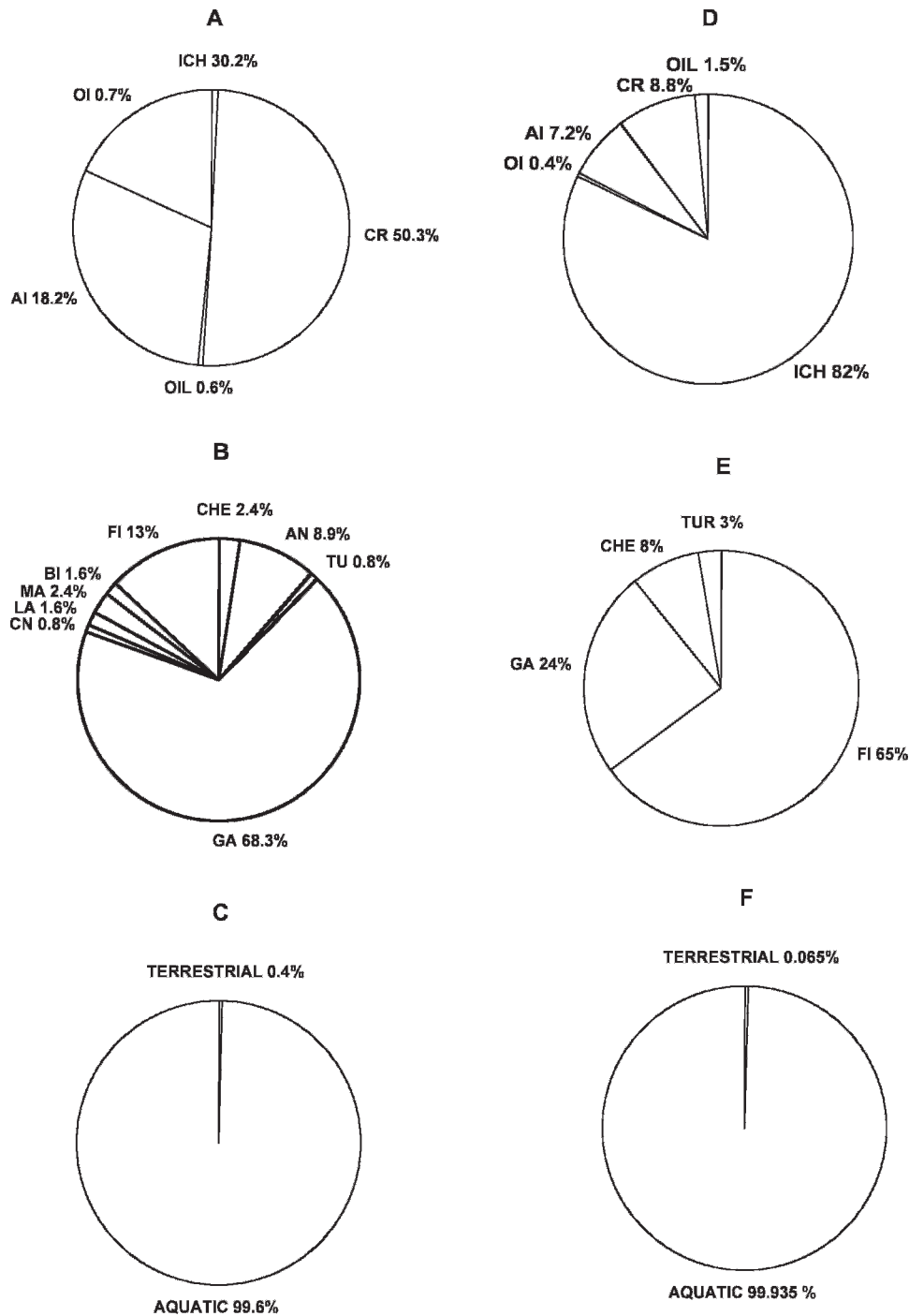


Figure 1. Pie charts showing prey category percentages for *Phrynops hilarii* (A–C) and *Hydromedusa tectifera* (D–F). A and D show the percentages of the most inclusive prey categories. B and E represent percentages of categories included within the “other” fraction shown in A and D. C and F are the percentages of terrestrial and aquatic prey items, respectively. Abbreviations: AI, adult insects; AN, annulata; BI, bird rests; CHE, chelicerata; CN, cnidaria; CR, crustacea; FI, fish; GA, gastropoda; ICH, immature chironomids; LA, larval anurans; MA, mammal rests; OI, other items; OIL, other insecta larvae; TU, turbellaria; TUR, turtle rests.

occurring for corixids in *P. hilarii*. Reasons for some prey preferences are difficult to determine, but we recommend that future studies should focus more attention on the preferred items that also have high diet contribution. Microcrustaceans are one of the most abundant items in the diet of the characiform fish ingested by the turtles studied by us (Escalante 1982, 1983). This would indicate

that microcrustaceans might have been ingested as “trojan” items. However, we prefer to reject this mechanism, at least for *P. hilarii*, because the 7 individuals that contained microcrustaceans had no trace of fish. As an alternative explanation, we believe that microcrustacean ingestion in *P. hilarii* occurred by neustophagia (see Belkin and Gans 1967). However, the

Table 2. Relative importance index values of each prey category for both studied species.

| <i>H. tectifera</i> | <i>P. hilarii</i> |
|--|--|
| Fundamental Immature Chironomidae (100) | Fundamental Immature Chironomidae (100) |
| Secondary Corixidae (50.09) | Accessory Corixidae (26.17) |
| Accidental Belostomatidae (9.18) Amphipoda (4.78) Copepoda (4.61) Pimelodidae (4.52) Zigoptera larvae (2.52) Characidae (1.98) Ephemeroptera larvae (1.37) Adult aquatic Coleoptera (0.81) Notonectidae (0.24) Sergestidae (0.14) Ostracoda (0.12) Poecilidae (0.12) Adult Ceratopogonidae; Planorbiidae; Ranatridae; Turtle rests; Hydrobiidae; Formicidae; Acrididae; Arrenuridae; Trichoptera larvae; Terrestrial Coleoptera; larval aquatic Coleoptera (each them lower than 0.1) | Accidental Belostomatidae (20.03) Mammal rests (5.5) Characidae (2.95) Copepoda (2.75) Cladocera (2.7) Terrestrial Coleoptera (1.78) Adult aquatic Coleoptera (1.49) Amphipoda (1.39) Bird rests (0.75) Hydrobiidae (0.49) Hydrudinea (0.48) Ostracoda (0.32) Lepidoptera larvae (0.14) Ephemeroptera larvae (0.13) Notonectidae; Zigoptera larvae; Formicidae; Acrididae; Arrenuridae; Trichoptera larvae; Hydrozoa; Trychodactylidae; Turbellaria; Muscidae larvae; Culicidae larvae; adult Culicidae; unidentified adult Diptera; Isopoda; Sirphidae larvae; larval aquatic Coleoptera; Hymenoptera unidentified; unidentified terrestrial Heteroptera; Loricariidae; Auchenorrhyncha; Ampullaridae; Lycosidae; Anuran larvae; adult Simuliidae; adult Muscidae; Anisoptera larvae; Aquatic Oligochaeta; Poecilidae (each them lower than 0.1) |

situation is different in *H. tectifera*, with microcrustaceans present in 6 individuals and 4 of these also containing fish remains, suggesting that the species ingested microcrustaceans as trojan items.

Turtles of both studied species ingested large amounts of immature chironomids of the genus *Chironomus*. The fact that there are very few areas of the sampled sections of Arroyo Buñirigo that have soft bottoms with interstitial spaces indicates that chironomids are easy prey for turtles. In fact, these chironomids usually live over the hard stream bottom and are frequently found over algae, trunks, and other submersed substrates. Similar situations of diets based on large quantities of immature chironomids have been reported for turtle populations that survive in polluted habitats, as occurs in *Chrysemys picta*, *Graptemys pseudogeographica*, and *Phrynops geoffroanus* (Knight and Gibbons 1968; Moll 1976; Souza and Abe 2000). Curiously, these species have a non-chironomid diet in populations from unpolluted waters. Cooley et al. (2003) described the diet of 2 populations of *C. picta* and found that the most ingested items were gastropods, naiads, trichopteran larvae, terrestrial isopods, and aquatic vegetation but not immature chironomids. Similarly, Dias and Souza (2005) and Fachin-Terán et al. (1995) reported that individuals of *P. geoffroanus* from unpolluted habitats ate fish, macrocrustaceans, mollusks, insects, and fruits of river-margin trees.

There are no published data on the diet of *H. tectifera*, and the only data for *P. hilarii* are those of Richard (1999) describing the diet of 2 feral populations

from artificial unpolluted lakes. He reported a diet based on small fish, shrimps, naiads, aquatic coleopterans, larval culicids, aquatic hemipterans (belostomatids and corixids), tadpoles, and some terrestrial insects (lepidopterans, orthopterans) but not chironomids. We hypothesize a pattern in which a generalist species experiences radical changes in diet composition in accord with environmental variations affecting prey abundance. Diet displacement from a non-chironomid to a chironomid-based diet fits this pattern. Similar displacements in trophic ecology

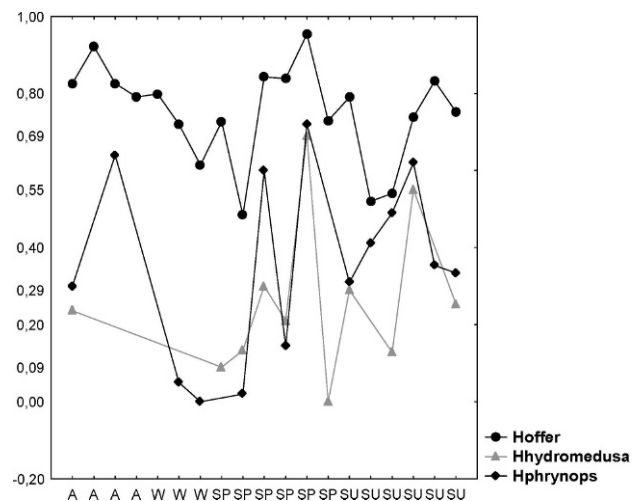


Figure 2. Seasonal variation of the H' indices for prey abundance and diet of both species studied. Abbreviations: A, autumn; SP, spring; SU, summer; W, winter.

Table 3. Seasonal variation in prey items among seasons and species and prey abundance, compared using Chi-square tests. Spaces without data indicate absence of the item. Boldface values represent significant differences between seasons (calculated $\chi^2 >$ table χ^2 at $\alpha = 0.05$) and in such cases, the null hypothesis was rejected (see data analysis).

| Item | Prey [A–W vs. S–S (χ^2)] | <i>H. tectifera</i> [A–W vs. S–S (χ^2)] | <i>P. hiliarii</i> [A–W vs. S–S (χ^2)] |
|-------------------|--|--|---|
| Fish | 1253 vs. 1812 (101.94 > 3.8) | 6 vs. 19 (6.8 > 3.8) | 5 vs. 12 (2.93 < 3.8) |
| Odonata larvae | 758 vs. 363 (138.61 > 3.8) | 38 vs. 11 (14.89 > 3.8) | 4 vs. 4 (0.125 < 3.8) |
| Crustacea | 437 vs. 1248 (393.34 > 3.8) | 24 vs. 201 (139.23 > 3.8) | 5 vs. 8292 (8277 > 3.8) |
| Hydrudinea | 2 vs. 3 (0.4 < 3.8) | | 9 vs. 1 (6.5 > 3.8) |
| Acari | 3 vs. 7 (1.7 < 3.8) | 3 vs. 0 (3.26 < 3.8) | |
| Aquatic | | | |
| Coleoptera | 55 vs. 53 (0.045 < 3.8) | 4 vs. 5 (0.2 < 3.8) | 8 vs. 63 (44.61 > 3.8) |
| Hemiptera | 230 vs. 269 (2.04 < 3.8) | 6 vs. 800 (782.17 > 3.8) | 60 vs. 1957 (1784.1 > 3.8) |
| Ephemeroptera | 24 vs. 4 (22.51 > 3.8) | 83 vs. 0 (83 > 3.8) | 57 vs. 0 (57.008 > 3.8) |
| Diptera larvae | 733 vs. 7 (713.26 > 3.8) | 3590 vs. 3 (3581 > 3.8) | 4925 vs. 108 (2305 > 3.8) |
| Gastropoda | 88 vs. 320 (131.92 > 3.8) | 2 vs. 5 (1.42 < 3.8) | 0 vs. 44 (44.02 > 3.8) |
| Trichoptera | | 3 vs. 0 (3.26 < 3.8) | |
| Tetrapods | | | 1 vs. 5 (2.83 < 3.8) |
| Terrestrial items | | 3 vs. 3 (0.166 < 3.8) | 4 vs. 50 (39.2 > 3.8) |

appear well supported in published data about fish diets (Tobler 2008). However, specialized turtles, such the strictly piscivorous *Chelus fimbriata* (Fachin-Terán 1995) or the molluscivorous females of *Graptemys* spp. (Lindeman and Sharkey 2001), seem to change diet composition across different environments less radically than in generalized species.

Diet Diversity. — There are few studies comparing the diet of freshwater turtles living in syntopy. It has been studied for the following syntopic pairs and assemblages: *Sternotherus minor*–*Sternotherus odoratus* (Berry 1975), *Graptemys geographica*–*Graptemys ouachitensis*–*G. pseudogeographica* (Vogt 1981), *Kinosternon flavescens*–*Emydoidea blandingii* (Kofron and Schreiber 1985), *Kinosternon leucostomum*–*Staurotypus triporcatus*–*T. scripta*

Table 4. Prey abundance variation between males and juveniles of *Phrynops hiliarii* tested using Chi-square tests. Boldface values represent significant differences between males and juveniles (calculated $\chi^2 >$ table χ^2 at $\alpha = 0.05$), and in such cases, the null hypothesis was rejected (see data analysis).

| Item | Sex | N | M VS. J (χ^2) |
|--------------------|-----|------|-------------------------|
| Fish | M | 11 | 2.31 < 3.8 |
| | J | 5 | |
| Odonata larvae | M | 7 | 5.5 > 3.8 |
| | J | 2 | |
| Crustacea | M | 8288 | 8312 > 3.8 |
| | J | 3 | |
| Hydrudinea | M | 10 | 10.1 > 3.8 |
| | J | 0 | |
| Aquatic Coleoptera | M | 30 | 3 < 3.8 |
| | J | 45 | |
| Hemiptera | M | 1892 | 1555.55 > 3.8 |
| | J | 122 | |
| Ephemeroptera | M | 57 | 57.1 > 3.8 |
| | J | 0 | |
| Diptera larvae | M | 4989 | 4942.8 > 3.8 |
| | J | 48 | |
| Gastropoda | M | 83 | 83.1 > 3.8 |
| | J | 0 | |
| Tetrapods | M | 5 | 0.68 < 3.8 |
| | J | 2 | |
| Terrestrial items | M | 26 | 0.019 < 3.8 |
| | J | 26 | |

(Vogt and Guzman Guzman 1988), and *Podocnemis unifilis*–*Podocnemis expansa*–*Phrynops geoffroanus*–*Mesoclemmys raniceps*–*C. fimbriata* (Fachin-Terán et al. 1995). Most of these cases show absence of competition for food resources except by *S. minor* and *S. odoratus*. Although there is no niche overlap between *P. hiliarii* and *H. tectifera*, both them show a tendency toward consumption of large quantities of immature chironomids as adaptation to habitat disturbance.

Seasonal Variation. — Seasonal variation of diet composition occurs in many species, but most studies do not correlate diet variations with the seasonal abundance of prey items. In fact, very few studies have included estimations of environmental abundance of prey items (e.g., Parmenter 1980; Spencer et al. 1998), and none of them has studied prey abundance during more than one season. Diet abundance varied seasonally for 6 prey items consumed by *H. tectifera* and for 8 ingested by *P. hiliarii*. Both species varied the consumption of 3 item categories in relation to seasonal variation of prey abundance. This was the case for dipteran larvae, ephemeropteran larvae, and crustaceans. Of the items consumed by *H. tectifera*, 33% varied in relation with prey abundance, whereas of those consumed by *P. hiliarii*, 66% correlated with seasonal variations. These differences indicate more dependence of *H. tectifera* on seasonal variation of particular prey items.

Prey and Turtle Sizes. — Both species studied herein consumed prey items within a similar range of total length (0.5–0.7 mm to 40–46 mm), and there was no significant correlation between turtle size and prey size. However, several studies show that correlations between prey item size and turtle size are usually positive, with the largest turtles being those that eat the largest items. Bury (1986) reported that differences in prey size between juveniles, males, and females of *Actinemys marmorata* diminished intraspecific competition for resources. Prévot-Julliard et al. (2007) studied the diet of feral populations of *Trachemys scripta elegans* from France and found that juveniles consumed more invertebrates than adults in

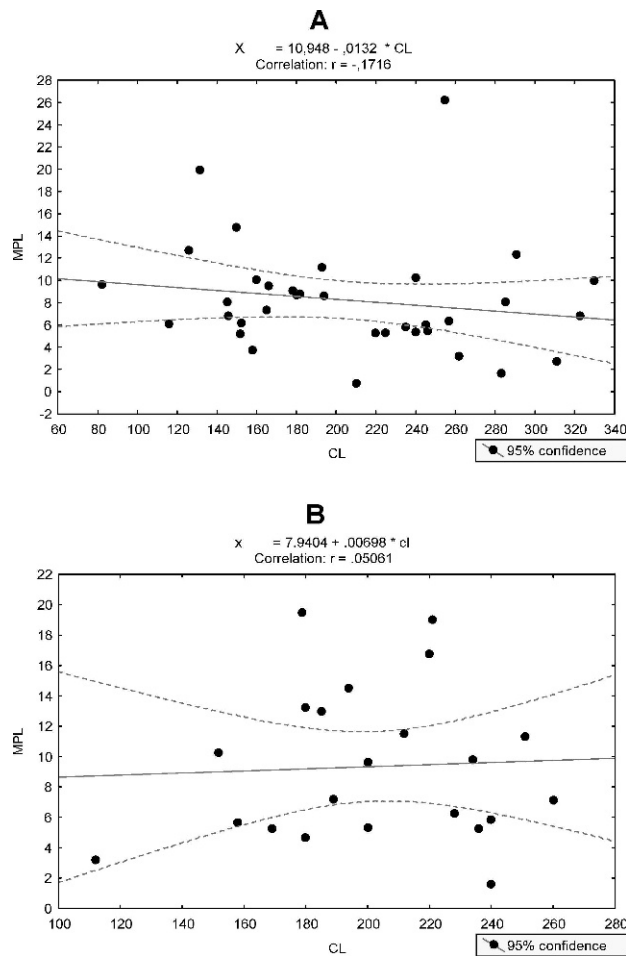


Figure 3. Pearson correlation between size of turtles (x-axis; straight-line carapace length in mm) and mean size of prey items (y-axis; mean prey length in mm) for *Phrynops hilarii* (A) and *Hydromedusa tectifera* (B).

relation to turtle size. Lahanas (1982) described a positive correlation between the size of the snails preyed upon by *Graptemys nigrinoda*, with the largest turtles eating the largest snails. Georges (1982) for *Emydura macquarii krefftii* and Tucker et al. (1995) for *Malaclemys terrapin* also described positive correlations between turtle size and prey size. Wilson and Lawner (2008) reported that large specimens of *E. m. krefftii* consumed lesser amounts of *Cabomba* and fruits of *Ficus* than did smaller turtles, without commenting on the size of such items. Souza and Abe (2000) did not find any correlation between turtle size and prey item size for *Phrynops geoffroanus*.

Long-Necked Chelids and Piscivory. — Particular and divergent morphological patterns within some groups are usually related to ecological adaptation. A clear example is the hypothesis that proposes piscivory for crocodylians with slender snouts relative to cranial length (Iordansky 1973). But this hypothesis is not always based on evidence, because these crocodylians reflect a more diverse diet than expected for piscivorous forms (Tucker et al. 1996). An alternative hypothesis proposes that slender snouts represent adaptation to living in riverine

habitats (Magnusson et al. 1987). Similarly, Pritchard (1984) proposed that the long neck of some chelid turtles would increase their capability of feeding on agile prey, particularly fish, but studies on the diet of long-necked chelids have not always supported the relationship between piscivorous habits and long necks. Fish consumption as carrion was reported for *E. m. krefftii* (Wilson and Lawner 2008); *E. macquarii* (Spencer et al. 1998); *G. pseudogeographica*, *G. geographica*, and *G. ouachitensis* (Vogt 1981); *Kinosternon sonoriense* (Hulse 1974); and some populations of *T. s. elegans* (Parmenter 1980; Prévot-Julliard et al. 2007). However, other aquatic turtles are capable of active predation upon small fish. Table 5 shows the published percentages of occurrence frequency, numeric frequency, and relative total volume for fish consumption of many species of freshwater turtles. This table makes 3 interesting points: 1) the only long-necked pleurodiran that completely occupies the piscivorous feeding niche is *C. fimbriata*; 2) contrary to the expected, some long-necked pleurodirans that live in environments in which fish are common do not feed upon them, as in *Hydromedusa maximiliani* and *Chelodina longicollis*; 3) the amount of fish fed upon by some long-necked pleurodirans (such as *H. tectifera*) do not differ from the amount ingested by short-necked turtles, and in some extreme cases, fish consumption is lower in long-necked pleurodirans than in short-necked species. The finding that *Chelus* is the species that best correlates with piscivorous habits is in agreement with the better capabilities of the species for suction feeding in comparison with other aquatic turtles, as has been demonstrated in works on turtle feeding kinematics (Lauder and Prendergast 1992; Van Damme and Aerts 1997; Summers et al. 1998; Aerts et al. 2001; Lemell et al. 2002). Differences in neck length between *H. tectifera* and *P. hilarii* are not expressed in dietary composition differences, because immature chironomids are the bulk of the diet in both species. Finally, the extant data and the evidence presented herein do not support the hypothesis that longer necks have a better capability of preying upon fish. Although some prey are capable of rapid movements (e.g., aquatic hemipterans, decapods), we do not consider them as agile, because they spend most of the time either quiet or making slow movements. We consider that nonagile prey represent 80% of the items ingested by the long-necked *H. tectifera*, with fish and other agile prey representing only a small fraction of the trophic spectrum of the species.

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Table 5. Literature-based list of turtle species that feed actively upon fish. The table includes the following percentages: occurrence frequency (%OF), numeric frequency (%NF) and percentage of total volume (%TV). The symbol (?) indicates no available data.

| Species | Source | Fish | | |
|----------------------------------|--|----------|-----------|---------------|
| | | %FN | %OF | %TV |
| Short-Necked Cryptodirans | | | | |
| <i>Actinemys marmorata</i> | Bury 1986 | 0.17 | 6.89 | 21.92 |
| <i>Emydoidea blandingii</i> | Kofron and Schreiber 1985 | 15.21 | 46.6 | ? |
| <i>Kinosternon flavescens</i> | Kofron and Schreiber 1985 | 6.79 | 44 | ? |
| <i>K. leucostomum</i> | Vogt and Guzman Guzman 1988 | ? | 10 | 9.1 |
| <i>Staurotypus triporcatus</i> | Vogt and Guzman Guzman 1988 | ? | 33.3–38.4 | 4.9–17.3 |
| <i>Trachemys scripta elegans</i> | Parmenter and Avery 1990; Outerbridge 2008 | ? | 16.92 | ? |
| Short-Necked Pleurodirans | | | | |
| <i>Acanthochelys spixii</i> | Richard 1999 | 9 | ? | ? |
| <i>A. pallidipectoris</i> | Richard 1999 | 7 | ? | ? |
| <i>Phrynops geoffroanus</i> | Fachin-Teran et al. 1995 | ? | ? | |
| | Dias and Souza 2005 | | | 29.8 |
| <i>P. hilarii</i> | Present paper | 0.096 | 36.17 | 3.13 |
| <i>Podocnemis unifilis</i> | Fachin-Teran et al. 1995 | ? | ? | 1.027 |
| <i>Rhinemys rufipes</i> | Caputo and Vogt 2008 | 3.8 | 19.4 | 23.5 |
| Long-Necked Pleurodirans | | | | |
| <i>Chelodina longicollis</i> | Georges et al. 1986 | 0 | 0 | 0 |
| <i>Chelus fimbriata</i> | Fachin-Teran et al. 1995 | 100 | 100 | 100 |
| <i>Hydromedusa tectifera</i> | Present paper | 0.259 | 36 | 14.25 |
| <i>H. maximiliani</i> | Souza and Abe 1995 | 0 | 0 | 0 |
| <i>Macrochelodina expansa</i> | Legler 1978 | ? | 7–25 | |
| | Chessman 1983 | | | 1.4–7.6 |
| <i>M. rugosa</i> | Kennett and Tory 1996 | 2.7–30.1 | 31.3–79.3 | 18.3–58.2 (g) |

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